Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (29–30 October 1986)

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A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on October 29 and 30, 1986 at the S. I. Vavilov Institute of Physical Problems of the USSR Academy of Sciences. The following reports were presented at the session:

October 29

1. *A. V. Gaponov-Grekhov and M. I. Rabinovich.* Nonlinear dynamics of nonequilibrium media: structures and turbulence.
2. *F. V. Bunkin, N. A. Kirichenko, and B. S. Luk'yanchuk.* Structures associated with laser oxidation of metals.

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3. *G. M. Zaslavskiĭ, R. Z. Sagdeev, D. A. Usikov, and A. A. Chernikov.* Stochastic web and structure generation.
4. *O. L. Shepelyanskiĭ.* Quantum chaos: diffusion photoeffect in hydrogen.
5. *G. P. Berman.* Some properties of quantum chaos.

Brief summaries of the reports are presented below.

A. V. Gaponov-Grekhov and M. I. Rabinovich. *Nonlinear dynamics of nonequilibrium media: structures and turbulence.* The nontraditional nature of problems in the modern dynamical theory of nonlinear nonequilibrium media is attributable primarily to structure formation and spatial development of turbulence. The study of these and similar phenomena requires the development of new models, methods, and, equally important, adequate examples and concepts which would apply to nonequilibrium media of arbitrary nature. In this report the theoretical and experimental results in the following directions are discussed (these are the most important current results): self-creation and formation of stable localized formations—"autostructures"[1–4]—in initially uniform media, transformation of structures of one type into structures of another type as the parameters of the medium change—"bifurcation of spatial images," the chaotic dynamics of ensembles of structures and transition to turbulence—"structural turbulence," lattice models,[5–8] appearance and development of turbulence (dynamic chaos) in flow systems—"spatial bifurcations,"[9] modeling of the process of growth of structures in excited media—"spatial self-development (self-construction) of structures."[10,11]

In the study of autostructures attention is devoted primarily to the mechanisms of their spatial localization and formation. It is shown using the example of thermocapillary convection in a plane layer with localized heating that the appearance of nontrivial solitary structures—regular polyhedra (in particular, hexahedral cells)—is determined by an additional nonlinearity, associated with the temperature dependence of the surface tension (or viscosity).[3] A model giving a qualitatively correct description of the observed structures for low subcriticality was constructed based on the Boussinesq equations. A two-dimensional model of a medium with liberation of heat, following from the equations of hydrodynamics and within whose framework solitary autostructures in the form of hexa- and tetrahedra (Fig. 1) were discovered (numerically), was proposed for the solution of the self-consistent problem.[4]

The bifurcation of spatial images is studied using the example of the creation of sources of spiral waves (reverberators). It has been shown[2] that the universality of the two-dimensional localized spiral structures observed in the most

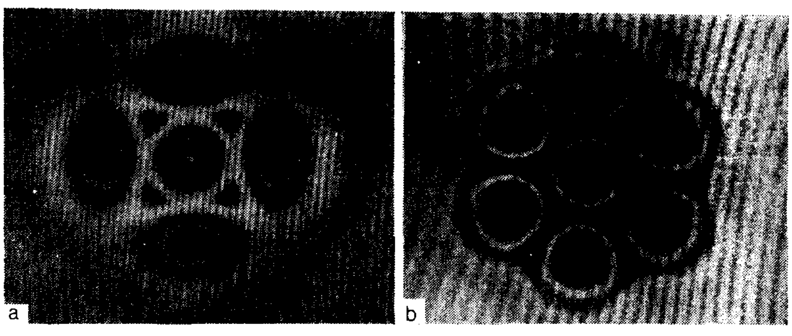

FIG. 1. Autostructures in the form of polyhedra in the system.

$$\frac{\partial u}{\partial t}=[(v-\alpha)-(1+\nabla^2)^2]\,u+\beta u^2-u^3,$$

$$\mu\frac{\partial v}{\partial t}=v-\delta v^3+\gamma u+D\Delta u\,.$$

The values of the parameters are: $-\alpha=0.3$, $\mu=0.05$; $\gamma=0.15$, $D=0.3$, $\beta=1.5$. $\delta=4$. a) Tetrahedron (the initial excitation $u(r_0,t_0)=0.75$ is given inside a circle with radius $R<7.0$). b) Hexahedron (the initial excitation is given in the circle $R>8.5$).

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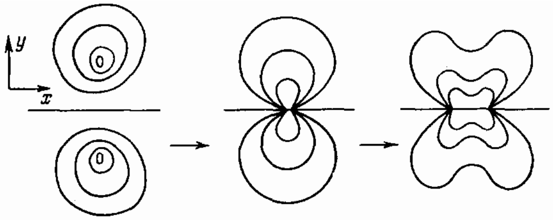

FIG. 2. Creation of spiral pairs as the supercriticality increases (the diffusion decreases) in the Ginzburg-Landau model:

$$\frac{\partial u}{\partial t}=u[1-(1+i\beta)\mid u\mid^2]+e\,(1-ic)\,\Delta u$$

diverse situations is linked with the general topological properties of some function $H_{t_0}(x, y)$ for example, for a two-component autocatalytic reaction H is the ratio of the concentrations of the components). To different structures of the two-dimensional field there are associated sheets of the function H. The creation of a new structure corresponds to the transition from one topological sheet to another. Sources of spiral vortices appear in a uniform medium at those points of space where the concentrations of the components vanish locally (Fig. 2).

As a rule, in nonequilibrium media it is not solitary autostructures that are observed but rather ensembles of such structures. As the degree of departure of the medium from equilibrium increases (for example, Rayleigh's number in thermoconvection) the regular dynamics of the ensemble of structures is replaced by a chaotic ensemble—turbulence appears. The appearance of a similar type (structural) of turbulence was discovered and studied in two-dimensional media, excited parametrically by uniform pumping. It has been shown for the example of Faraday ripples[5,6] that the appearance of chaos against the background of a regular ripple structure is linked with the development of quasiperiodic transverse modulation, transforming through intermittance into stochastic modulation. An equation which is a parametric variant of the Ginzburg-Landau equations was derived[1)]:

$$\frac{\partial a}{\partial t}=iha^*-\gamma a-i\delta a+iTa\mid a\mid^2-\frac{v_{\mathrm{gr}}}{2ik}\frac{\partial^2 a}{\partial y^2},$$

based on which all basic transitions to chaos in this system are described.[6]

The possibility of self-creation and development of turbulence of dynamic origin in flow systems (for example, hydrodynamic shear flows) is demonstrated for models consisting of a chain of sequentially coupled structures (in particular, vortices).[9] It has been shown with the help of the renormalization-group description[13] that the appearance of chaos (creation of a strange attractor) downstream is preceded by a finite number of spatial bifurcations—restructurings of the regular dynamics of the flow. The relationship between scenarios of spatial development of turbulence and the dynamics of elementary structures comprising the flow is discussed. The growth of the dimensionality of the stochastic set downstream was evaluated, and the effect of stabilization of the spatial development of chaos was observed. This corresponds to saturation of the dimensionality of the strange attractor. This effect is linked with the synchronization of the stochastic motions in neighboring structures.[14]

The so-called excitable media, which have a finite instability threshold, form a special class of nonequilibrium media. Structure formation processes in such media are characterized primarily by the "self-development" (self-construction) of structures in space. New effects discovered in modeling such media on the "TV analog"[10] and the "cell computer"[11]—coexistence of localized excitations, multistability; development of spatially disordered structures—are discussed.

[1)] We note here that the Ginzburg-Landau equation and its different generalizations play a fundamental role in the nonlinear dynamics of nonequilibrium media.[12]

[1] A. V. Gaponov-Grekhov and M. I. Rabinovich, Physics of the 20th Century: Development and Prospects (in Russian), Nauka, M., 1984, p. 219.
[2] I. S. Aranson and M. I. Rabinovich, Izv. Vyssh. Uchebn. Zaved., Radiofiz. **29**, No. 12 (1986) [Radiophys. Quantum Electron. (1986)].
[3] O. V. Vashkevich, A. V. Gaponov-Grekhov, A. B. Ezerskiĭ, and M. I. Rabinovich, Dokl. Akad. Nauk SSSR (1986) [*sic*].
[4] A. V. Gaponov-Grekhov, A. S. Lomov, and M. I. Rabinovich, Pis'ma Zh. Eksp. Teor. Fiz. **44**, 242 (1986) [JETP Lett. **44**, 310 (1986)].
[5] A. B. Ezerskiĭ, P. I. Korotin, and M. I. Rabinovich, Pis'ma Zh. Eksp. Teor. Fiz. **41**, 129 (1985) [JETP Lett. **41**, 157 (1985)].
[6] A. B. Ezerskiĭ, M. I. Rabinovich, V. P. Reutov, and I. M. Starobinets, Zh. Eksp. Teor. Fiz. **91**, 2070 (1986) [Sov. Phys. JETP **64**, 1228 (1986)].
[7] I. S. Aranson, A. V. Gaponov-Grekhov, and M. I. Rabinovich, Zh. Eksp. Teor. Fiz. **89**, 92 (1985) [Sov. Phys. JETP **62**, 52 (1985)].
[8] I. S. Aranson, A. V. Gaponov-Grekhov, M. I. Rabinovich, A. V. Rogal'skiĭ, and R. Z. Sagdeev, "Lattice models in the nonlinear dynamics of nonequilibrium media" (in Russian), Preprint of the Institute of Applied Physics of the USSR Academy of Sciences, Gor'kiĭ, 1986.
[9] I. S. Aranson, A. V. Gaponov-Grekhov, M. I. Rabinovich, and I. M. Starobinets, Zh. Eksp. Teor. Fiz. **90**, 1707 (1986) [Sov. Phys. JETP **63**, 1000 (1986)].
[10] V. N. Golubev *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. (1985) [JETP Lett. **42**, 99 (1985)].
[11] V. N. Golubev, M. I. Rabinovich, V. N. Tolkov, and V. G. Yakhno, Biomolecular Electronics (in Russian), Pushchino, 1986.
[12] A. V. Gaponov-Grekhov and M. I. Rabinovich, Izv. Vyssh. Uchebn. Zaved., Radiofiz. **30**, No. 4 (1987) [Radiophys. Quantum Electron. (1987)].
[13] I. S. Aranson and M. I. Rabinovich, "Renormalization-group description of the spatial development of turbulence" (in Russian), Preprint No. 152, Institute of Applied Physics of the USSR Academy of Sciences (1986).
[14] V. S. Afraĭmovich, N.N. Verichev, and M. I. Rabinovich, Izv. Vyssh. Uchebn. Zaved., Radiofiz. **29** (1986) [Radiophys. Quantum Electron. (1986)].